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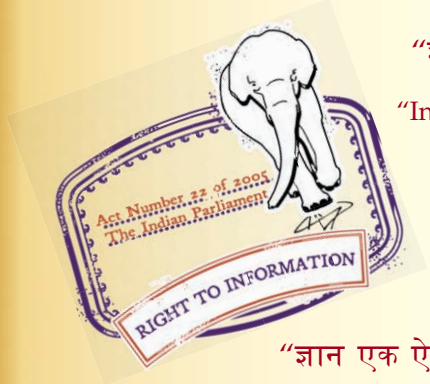

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IS : 8736 - 1977
(Reaffirmed 2003)

Indian Standard

SPECIFICATION FOR NICKEL AND NICKEL ALLOY COVERED ELECTRODES FOR METAL ARC WELDING

(First Reprint APRIL 1998)

UDC 621.791.753.042.4 : 669.24

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard

SPECIFICATION FOR NICKEL AND NICKEL ALLOY COVERED ELECTRODES FOR METAL ARC WELDING

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Indian Standard

SPECIFICATION FOR NICKEL AND NICKEL ALLOY COVERED ELECTRODES FOR METAL ARC WELDING

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 26 October 1977, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard has been prepared with a view to guiding the industry in the manufacture and selection of nickel and nickel alloy covered electrodes for manual metal arc welding. This standard includes only commonly used types of electrodes. A guide to classification and selection of electrodes is given for information in Appendix A.

0.3 This standard specifies a usability test which requires the use of nickel and nickel base alloys as the base material for preparing test specimens. Due to non-availability of the nickel and nickel base alloys in the country it may not be possible to conduct this test for the qualification of electrodes. The Sectional Committee, therefore, feels that this test may not be carried out in circumstances where the required nickel and nickel alloys are not available. This relaxation is subject to review after a period of three years from the date of publication of this standard.

0.4 This standard keeps in view the manufacturing and trade practices in the field in the country. Assistance has also been derived from AWS A 5.11-1976. 'Nickel and nickel alloy covered welding electrodes', issued by American Welding Society, New York, USA.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the requirements for nickel and nickel alloy covered electrodes for manual metal arc welding. The range of electrodes covered and the chemical composition of deposited weld metal are given in Table 1.

*Rules for rounding off numerical values (*revised*).

TABLE 1 CHEMICAL COMPOSITION FOR UNDILUTED WELD METAL, PERCENT

(*Clauses* 1.1, 8.2.2 *and* C-1.4)

IS Classification	C	Mn	Fe	P	S	Si	Cu	Ni*	Co	Al	Ti	Cr	Cb Plus Ta	Mo	V	W	Other Elements, Total
ENi-1	0·10	0·75	0·75	0·03	0·02	1·25	0·25	92·0 *Min*	—	1·0	1·0 to 4·0	—	—	—	—	—	0·50
ENiCu-7	0·15	4·0	2·5	0·02	0·015	1·0	Rem	62·0 to 68·0	—	0·75	1·0	—	—	—	—	—	0·50
ENiCrFe-1	0·08	3·5	11·0	0·03	0·02	0·75	0·50	62·0 *Min*	—	—	—	13·0 to 17·0	1·5 to 4·0‡	—	—	—	0·50
ENiCrFe-2	0·10	1·0 to 3·5	12·0	0·03	0·02	0·75	0·50	62·0	†	—	—	13·0 to 17·0	0·5 to 3·0‡	0·50 to 2·50	—	—	0·50
ENiCrFe-3	0·10	5·0 to 9·5	10·0	0·03	0·015	1·0	0·50	59·0 *Min*	†	—	1·0	13·0 to 17·0	1·0 to 2·5‡	—	—	—	0·50
ENiCrFe-4	0·20	1·0 to 3·5	12·0	0·03	0·02	1·0	0·50	60·0 *Min*	—	—	—	13·0 to 17·0	1·0 to 3·5	1·0 to 3·5	—	—	0·50
ENiMo-1	0·07	1·0	4·0 to 7·0	0·04	0·03	1·0	0·50	Rem	2·5	—	—	1·0	—	26·0 to 30·0	0·60	1·0	0·50
ENiMo-3	0·12	1·0	4·0 to 7·0	0·04	0·03	1·0	0·50	Rem	2·5	—	—	2·5 to 5·5	—	23·0 to 27·0	0·60	1·0	0·50

ENiCrMo-1	0·05	1.0 to 2·0	18·0 to 21·0	0·04	0·03	1·0	1·5 to 2·5	Rem	2·5	—	—	21·0 to 23·5	1·75 to 2·50	5·5 to 7·5	—	1·0	0·50
ENiCrMo-2	0·05 to 0·15	1·0	17.0 to 20·0	0·04	0·03	1·0	0·50	Rem	0·50 to 2·50	—	—	20·5 to 23·0	—	8·0 to 10·0	—	0·20 to 1·0	0·50
ENiCrMo-3	0·10	1·0	7·0	0·03	0·02	0·75	0·50	55·0 *Min*	†	—	—	20·0 to 23·0	3·15 to 4·15	8·0 to 10·0	—	—	0·50
ENiCrMo-4	0·02	1·0	4·0 to 7·0	0·04	0·03	0·2	0·50	Rem	2·5	—	—	14·5 to 16·5	—	15·0 to 17·0	0·35	3·0 to 4·5	0·50
ENiCrMo-5	0·10	1·0	4·0 to 7·0	0·04	0·03	1·0	0·50	Rem	2·5	—	—	14·5 to 16·5	—	15·0 to 18·0	0·35	3·0 to 4·5	0·50
ENiCrMo-6	0·10	2·0 to 4·0	10·0	0·03	0·02	1·0	0·50	55·0 *Min*	—	—	—	12·0 to 17·0	0·5 to 2·0	5·0 to 9·0	—	1·0 to 2·0	0·50

NOTE 1 — Analysis shall be made for the elements for which specific values are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for 'Other elements, total' in the last column in the table.

NOTE 2 — Single values shown are maximum percentage, except where otherwise specified.

*Includes incidental cobalt.

†Cobalt — 0·12 *Max* when specified.

‡Tantalum — 0·30 *Max* when specified.

1.2 Nickel base covered electrodes for welding cast irons are covered separately in IS : 5511-1969*.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 812-1957† shall apply.

3. SUPPLY OF MATERIAL

3.1 General requirements relating to supply of nickel and nickel alloy covered electrodes for shielded metal arc welding shall be as laid down in IS : 1387-1967‡.

4. CLASSIFICATION AND CODING

4.1 The coding of the electrode shall consist of a prefix letter E to indicate a covered electrode.

4.1.1 Since the electrodes are classified on the basis of chemical composition of the weld metal, the chemical symbol Ni is used to identify the electrodes as nickel based and the additional chemical symbols, such as Cr, Cu, Fe and Mo, in the designations indicate the principal alloying elements in each classification or series. The individual classifications within a series are identified by the number at the end of the designation, for example ENiCu-1, ENiCu-2.

Example of a Classification:

ENiCrFe-1

a) It is a covered electrode for manual metal arc welding.
b) The major element present in the deposited weld metal is nickel. Other principal elements are chromium and iron.
c) It is electrode type 1 in the NiCrFe series.

5. MANUFACTURE

5.1 The electrodes may be manufactured by any method yielding a product conforming to the requirements of this specification.

6. STANDARD SIZES AND LENGTH

6.1 The size of the electrodes shall be designated by the diameter of the

*Specification for covered electrodes for manual metal arc welding of cast iron.
†Glossary of terms relating to welding and cutting of metals.
‡General requirements for the supply of metallurgical materials (*first revision*).

core wire expressed in millimetres. The designation and size of the electrodes shall be as follows:

Designation of the Electrode Size	*Diameter of the Core Wire* mm
2	2·00
2·5	2·50
3·15	3·15
4	4·00
5	5·00
6·3	6·30

6.2 Tolerance on Size — The specified diameter of the core wire of the electrode shall not vary by more than ±0·05 mm.

6.3 Length — The length of various sizes of electrodes shall be as given below:

Size	*Length* mm
2·0	200 250 300 350
2·5	250 300 350
3·15 and over	350 450

6.4 Tolerance on Length — The tolerance on the length of individual electrodes over nominal length prescribed shall be ±3 mm.

7. GENERAL REQUIREMENTS

7.1 Core wires and coverings shall be free of defects which would interfere with uniform performance of the electrodes.

7.2 Exposed Core — The gripping end of the electrodes shall be bare and clean for a distance of about 20 mm, but not more than 30 mm, to provide for electrical contact with the holder.

7.2.1 The arc striking end of the electrodes shall be sufficiently bare to permit easy striking of the arc. Where the end is bare the length of the distance from the arc end to the first point where full cross section of the covering prevails shall not exceed 2 mm or half the diameter of the core wire whichever is the less.

7.3 Covering — The flux covering shall fulfil the following requirements:

a) *Strength* — The covering shall be sufficiently strong to withstand damage under normal conditions of handling, storage and use.

b) *Uniformity* — The covering shall be uniform in outside diameter and in thickness. The tolerance permitted for uniformity of covering shall be such that the maximum core-plus-one covering dimension (*see* Fig. 1) shall not exceed the minimum core-plus-one covering dimension by more than 5 percent of the mean of the two dimensions.

$$A-B \leqslant \frac{5}{100}\left(\frac{A+B}{2}\right)$$

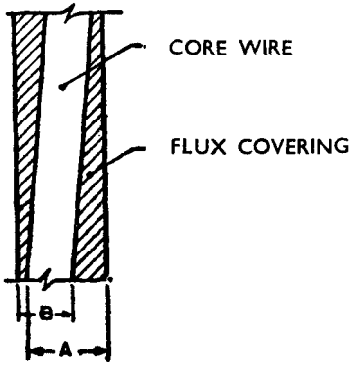


FIG. 1 PERMISSIBLE TOLERANCE FOR FLUX COVERING

7.3.1 The covering of an electrode shall fuse and/or burn evenly.

8. SPECIFIC REQUIREMENTS AND TESTS

8.1 For assessing the chemical composition, mechanical properties and soundness of the deposited weld metal and the usability of the electrodes classified herein, the electrodes shall be subjected to the following tests:

a) Initial tests,

b) Periodic check tests, and

c) Production control tests.

8.1.1 The parent metal used for test plates shall conform to the requirements specified in Appendix B.

8.2 Initial Tests — These are qualifications or proving tests for a particular type of electrode manufactured with certain qualities of basic material and under certain production conditions. Each type of electrode shall be subjected to the initial tests and it shall be implicit in the manufacturer's certificate that the electrodes certified by him conform to specific classification, and satisfy all test requirements prescribed for initial test for that particular classification.

8.2.1 The initial tests for electrodes shall comprise the following:

a) Chemical analysis (*see* **8.2.2** and Appendix C),
b) All-weld metal tensile test (*see* **8.2.3** and Appendix D),
c) Transverse guided side bend test (*see* **8.2.4** and Appendix D),
d) Surfacing weld bend test (*see* **8.2.5** and Appendix E), and
e) Usability test (*see* **8.2.6** and Appendix F).

8.2.1.1 A summary of test requirements for different classifications and sizes of electrodes are given in Table 2. Tests are required only where base metals are indicated. The tests are to be conducted in the as-welded condition that is without any further heat treatment.

TABLE 2 SUMMARY OF TESTS REQUIRED

(*Clauses* 8.2.1.1, 8.2.5, 8.2.6, C-1.1, D-1.1, D-3.1, E-1 *and* F-3)

IS Classification	Electrode Size	Base Metal*					
		Chemical Analysis†	All-Weld Metal Tensile Test‡	Transverse Guided Bend Test§	Surfacing Weld Bend Test	Usability Test ‖	
(1)	(2) mm	(3)	(4)	(5)	(6)	(7)	(8)
ENi-1	2·0	Ni	Ni or steel	—	Steel	Ni	V
	2·5						V
	3·15						V
	4·0						F
	5·0						F
	6·3						F
ENiCu-7	2·0	Ni-Cu	Ni-Cu	Ni-Cu	—	Ni-Cu	V
	2·5						V
	3·15						V
	4·0						F
	5·0						F
	6·3						F
ENiCrFe-1	2·0	Ni-Cr-Fe or steel	Ni-Cr-Fe or steel	Ni-Cr-Fe or steel	—	Ni-Cr-Fe	V
	2·5						V
	3·15						V
	4·0						F
	5·0						F
	6·3						F
ENiCrFe-2, ENiCrFe-3, ENiCrFe-4	2·0	Ni-Cr-Fe	Ni-Cr-Fe or steel	Ni-Cr-Fe or steel	Steel	Ni-Cr-Fe or steel	V
	2·5						V
	3·15						V
	4·0						F
	5·0						F
	6·3						F
ENiMo-1, ENiMo-3	2·0	Ni-Mo	Ni-Mo or steel	Ni-Mo or steel	—	Ni-Mo	F
	2·5						F
	3·15						F
	4·0						F
	5·0						F
	6·3						F

(*Continued*)

TABLE 2 SUMMARY OF TESTS REQUIRED — *Contd*

IS Classification	Electrode Size	Base Metal*					
		Chemical Analysis†	All-Weld Metal Tensile Test‡	Transverse Guided Bend Test§	Surfacing Weld Bend Test	Usability Test ‖	
(1)	(2) mm	(3)	(4)	(5)	(6)	(7)	(8)
ENiCrMo-1	2·0	Ni-Cr-Mo	Ni-Cr-Mo or steel	—	—	Ni-Cr-Mo	F
	2·5						F
	3·15						F
	4·0						F
	5·0						F
	6·3						F
ENiCrMo-2	2·0	Ni-Cr-Mo	Ni-Cr-Mo or steel	Ni-Cr-Mo or steel	—	Ni-Cr-Mo	F
	2·5						F
	3·15						F
	4·0						F
	5·0						F
	6·3						F
ENiCrMo-3 / ENiCrMo-6	2·0	Ni-Cr-Mo	Ni-Cr-Mo or steel	Ni-Cr-Mo or steel	Steel	Ni-Cr-Mo	V
	2·5						V
	3·15						V
	4·0						F
	5·0						F
	6·3						F
ENiCrMo-4	2·0	Ni-Cr-Mo	Ni-Cr-Mo or steel	Ni-Cr-Mo or steel	—	Ni-Cr-Mo	F
	2·5						F
	3·15						F
	4·0						F
	5·0						F
	6·3						F
ENiCrMo-5	2·0	Ni-Cr-Mo	Ni-Cr-Mo or steel	—	—	Ni-Cr-Mo	F
	2·5						F
	3·15						F
	4·0						F
	5·0						F
	6·3						F

*Tests are required only where base metals are designated. All welding for chemical analysis, all-weld tensile test, transverse guided side bend test, and surfacing weld bend test shall be done with the test plates in the flat position.

†When desired, base metals other than those specified may be used for chemical analysis test pads, provided the minimum pad height is 20 mm and the sample taken for analysis is removed from the pad no closer than 15 mm from the base metal.

‡When desired, steel may be substituted for the designated nickel alloy in the all-weld metal tensile test and the transverse guided side bend test. When this is done, buttering shall be applied to the fusion faces of the joint and the mating surface of the backing strip. Buttering shall be applied with electrodes of the same classification as those being tested and may be done in the flat position.

§Six transverse side bend tests are required except for 2·0 mm electrodes. For that size two transverse face bends are used.

‖ Position of welding to be used only for the usability test. V = vertical, F = flat.

8.2.2 *Chemical Analysis* — The chemical analysis of the weld metal deposit shall be carried out as specified in Appendix C. The chemical composition shall be in accordance with Table 1.

8.2.3 *All-Weld Metal Tensile Test* — All-weld metal tensile tests shall be conducted in accordance with the method specified in Appendix D. The test results shall conform to Table 3.

TABLE 3 ALL-WELD METAL TENSILE TEST REQUIREMENTS

IS Classification	Tensile Strength (*Min*)		Minimum Elongation on Gauge Length of 4 × Diameter, Percent
	MPa	(kgf/mm²)	
(1)	(2)	(3)	(4)
ENi-1	410	(42)	20
ENi Cu-7	480	(49)	30
ENiCrFe-1, ENiCrFe-2, ENiCrFe-3	550	(56)	30
ENiCrFe-4	650	(66)	20
ENiMo-1, ENiMo-3	690	(70)	25
ENiCrMo-1	620	(63)	20
ENiCrMo-2	650	(66)	20
ENiCrMo-3	760	(77)	30
ENiCrMo-4	690	(70)	25
ENiCrMo-5	690	(70)	25
ENiCrMo-6	620	(63)	35

8.2.4 *Transverse Weld Bend Test* — Transverse guided side bend and face bend tests as required in Table 2 shall be conducted in accordance with the procedure specified in Appendix D. The weld metal after bending shall not exhibit evidence of fissuring in excess of the requirements of Table 4, when examined by the unaided eye.

8.2.5 *Surfacing Weld Bend Test* — Surfacing bend tests as required in Table 2 shall be conducted in accordance with the procedure specified in Appendix E. The weld metal after bending shall not exhibit evidence of fissuring in excess of the requirements in Table 4, when examined by the unaided eye.

8.2.6 *Usability Test* (*see* **0.3**) — The usability test as required in Table 2 shall be conducted in accordance with the procedure given in Appendix F. The test is evaluated by radiography. The radiographs shall indicate no cracks or zones of incomplete fusion, nor porosity, nor slag inclusions in excess

TABLE 4 BEND TEST REQUIREMENTS

(*Clauses* 8.2.4, 8.2.5 *and* E-7)

IS Classification	Electrode Size	Fissures Permitted	
		Length	Number
(1)	(2)	(3) mm	(4)
ENi-1	2·0, 2·5, 3·15	3·0	3
	4·0, 5·0, 6·3	3·0	4
ENi-Cu-7	2·0, 2·5, 3·15	2·5	3
	4·0, 5·0, 6·3	2·5	4
ENiMo-1, ENiMo-3, ENiCrFe-1, ENiCrFe-2, ENiCrFe-4, ENiCrMo-2, ENiCrMo-3, ENiCrMo-4, ENiCrMo-6	2·0, 2·5, 3·5, 4·0, 5·0, 6·3	2·5	3
ENiCrFe-3	2·0, 2·5, 3·5, 4·0, 5·0, 6·3	2·5	2

NOTE 1 — These requirements apply to both transverse guided side bend, face bend and surfacing weld bend test specimens.

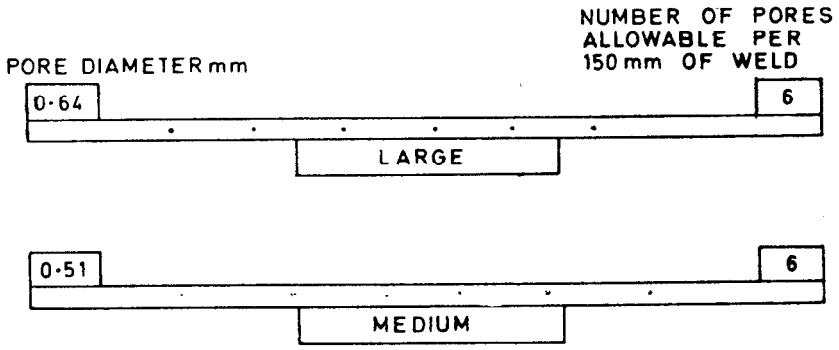
NOTE 2 — Maximum number of fissures permissible and maximum length for each fissure in each bend test specimen.

NOTE 3 — Fissures 0·5 mm and shorter shall not be counted.

NOTE 4 — The corners of specimens shall not be considered when evaluating the result.

NOTE 5 — For 2·0 mm electrodes, substitute two transverse face bends for the six side bends.

of the amount permitted in Fig. 2 for 3·15 mm test plate, Fig. 3 for the 6·3 mm test plate, Fig. 4 for the 10 mm test plate and Fig. 5 for the 12 mm test plate.



NOTE — In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

FIG. 2 RADIOGRAPHIC POROSITY ACCEPTANCE STANDARD FOR 3·15 mm TEST PLATE

8.3 Periodic Check Tests — These comprise a few of the tests selected from amongst the initial tests and are meant to be repeated at intervals to provide evidence that the electrodes currently produced pass the properties proved in the initial tests. Such tests shall be conducted at least once a year. These check tests shall not apply to the electrodes not manufactured during the period.

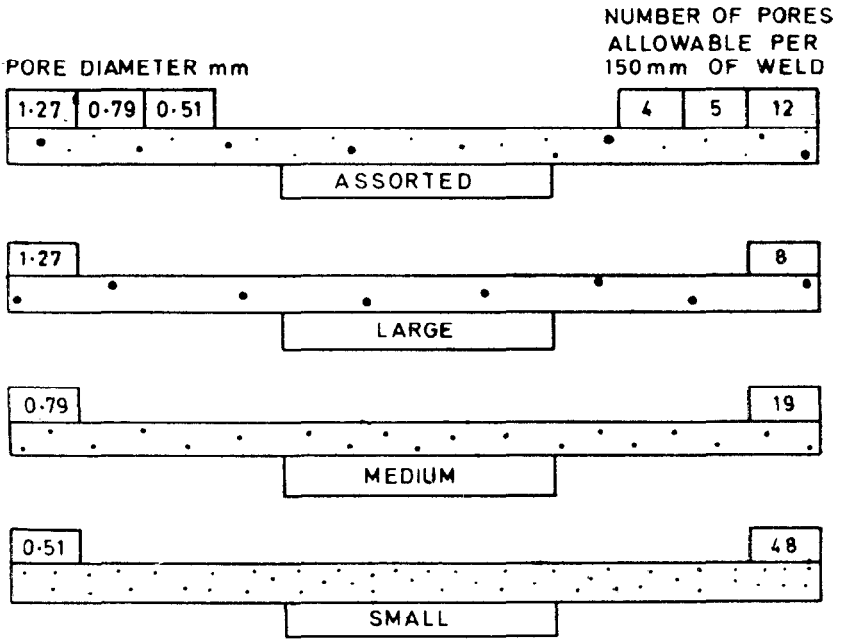
8.3.1 The periodic check tests shall comprise the following:

a) Chemical analysis (*see* **8.2.2** and Appendix C).

b) Surfacing weld bend test (*see* **8.2.5** and Appendix E).

8.4 Production Control — By means of a suitable system of control, the manufacturer shall satisfy himself that the composition and quality of all the electrodes currently produced are similar to those of the electrodes subjected to the initial tests (*see* **8.2**). He shall ensure that the results of production control tests and the date of manufacture can be traced from the batch number of the relevant details, or both given on the label.

NOTE — For this purpose, a batch is defined as being of the same dry mix, and the same cast number of wire.



NOTE — In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

FIG. 3 RADIOGRAPHIC POROSITY ACCEPTANCE STANDARD FOR 6·3 mm TEST PLATE

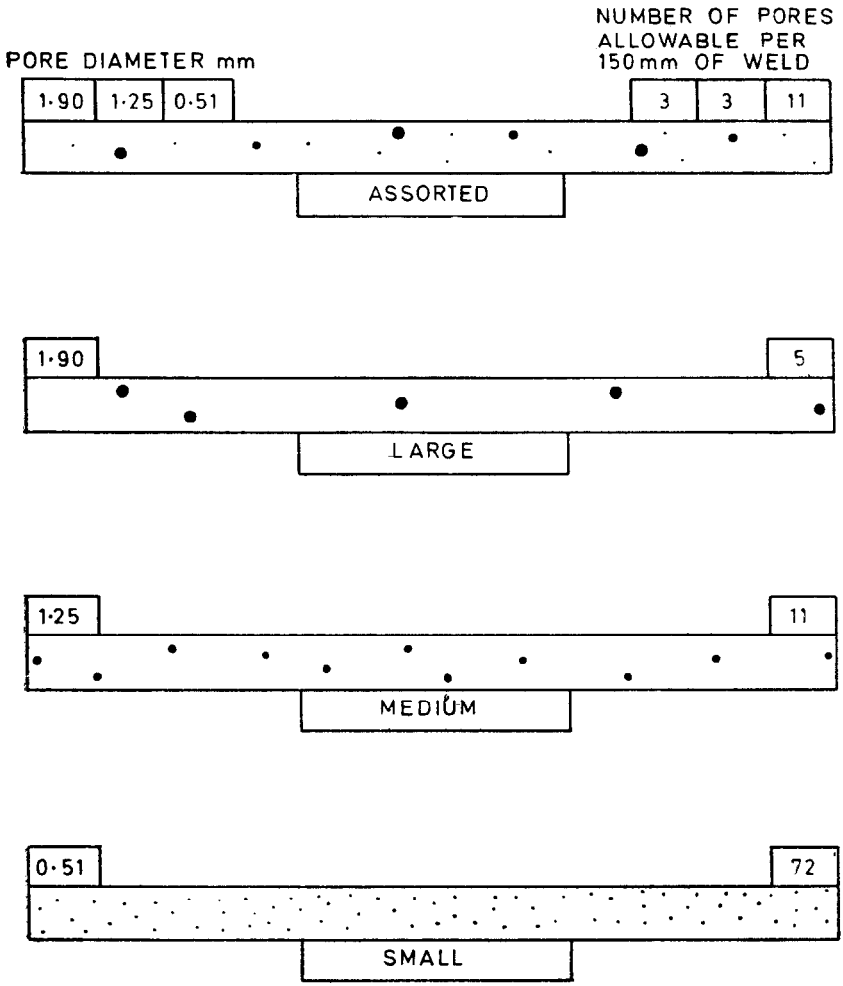
8.5 Additional Tests — Subject to agreement with the supplier, the purchaser may request for additional tests to be made or certificates to be provided for each batch of electrodes supplied. If so the tests and batch definition shall be as agreed to between the purchaser and the supplier.

9. RETESTS

9.1 Where any test specimen fails to satisfy the test requirements, two further test specimens shall be prepared (using electrodes from the same batch) and submitted to the test in which the requirements were not fulfilled. The electrodes shall be deemed as not complying with this standard unless the test on both the additional specimens are satisfactory.

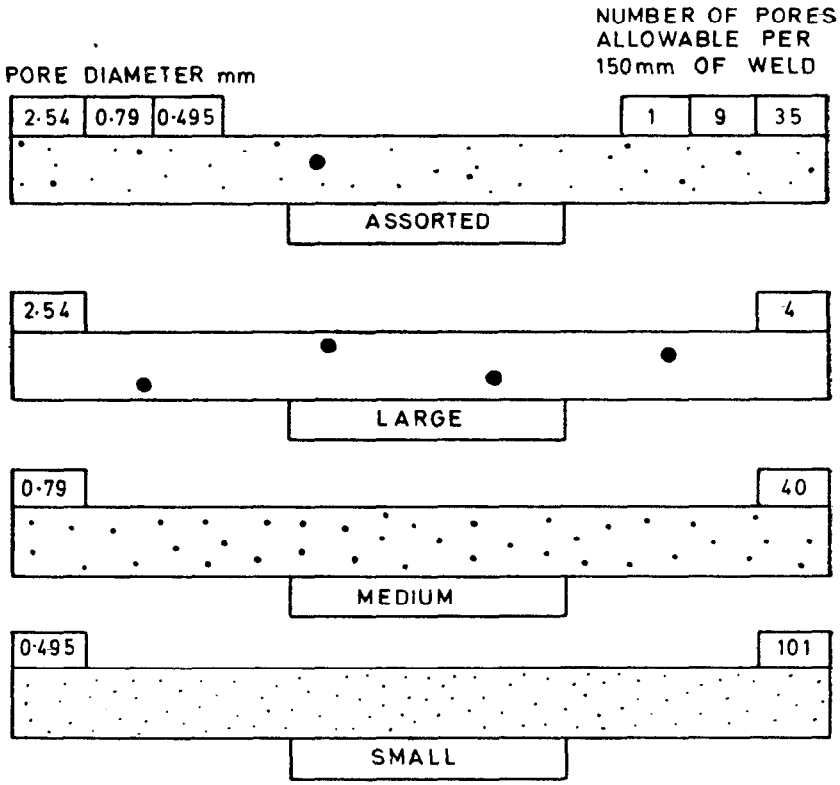
10. PACKING AND STORAGE

10.1 The net mass of an individual bundle, carton or box of electrodes shall not exceed 7 kg.



NOTE — In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

FIG. 4 RADIOGRAPHIC POROSITY ACCEPTANCE STANDARD FOR 10 mm TEST PLATE



NOTE — In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

FIG. 5 RADIOGRAPHIC POROSITY ACCEPTANCE STANDARD FOR 12·0 mm TEST PLATE

10.2 Electrodes shall be suitably packed to guard against damage during transportation. The packing shall be suitable to ensure that under normal storage conditions, the electrodes shall, for a period of at least six months after the despatch from the manufacturer's stores, be capable of giving results in accordance with the provisions of this specification; and that if the flux covering is of a type requiring special protection during storage, the details of such special protection shall be furnished by the manufacturer and reference to this shall be included in the marking of the bundle, carton or box of electrodes. The electrodes shall be stored in dry room.

10.3 Each bundle of electrodes shall contain the manufacturer's certificate to guarantee that the electrodes therein comply with the mechanical and chemical requirements specified in this standard.

10.3.1 If the marking on the bundle includes ISI Certification Mark (*see* **12.1.1**), the manufacturer's certificate may not be included.

11. TEST RESULTS

11.1 If required by the purchaser, in evidence that the electrodes supplied comply with requirements of this specification, the manufacturer shall produce the results of the most recent periodic check tests carried out within the preceding 12 months on electrodes representative of the electrodes supplied.

11.2 If required, the manufacturer shall supply a test certificate giving the results of the initial tests carried out on the type of electrode supplied.

11.3 If required by the purchaser, the manufacturer shall furnish a test certificate by mutual agreement for each batch of electrode supplied.

12. MARKING

12.1 Each bundle, carton or packet of electrodes shall be clearly marked with the following (*see also* **10.2**, **10.3** and **10.3.1**):

a) Code designation (*see* **4**);
b) Name of the manufacturer;
c) Trade designation (brand name) of electrodes;
d) Size (size designation and length) (*see* **6**);
e) Batch number (*see* **8.4**);
f) Date of manufacture;
g) Quantity (in numbers or weight or both); and
h) Recommendations for special storage condition, if necessary (*see* **10.2**).

12.1.1 The bundle, carton or packet of electrodes may also be marked with the Standard Mark.

12.2 The use of the Standard Mark is governed by the provisions of *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manfucaturers or producers may be obtained from the Bureau of Indian Standards.

APPENDIX A

(*Clause* 0.2)

GUIDE TO IS CLASSIFICATION OF NICKEL AND NICKEL ALLOY COVERED WELDING ELECTRODES

A-1. INTRODUCTION

A-1.1 This guide is given for information only. It correlates the electrode classifications with their intended applications so that this specification may be used effectively.

A-2. CLASSIFICATION SYSTEM

A-2.1 The system of classifying nickel and nickel alloy covered electrodes is given in **4.**

A-2.2 It is recognized that supplementary tests may be required for certain applications. In such cases, additional tests to determine specific properties such as corrosion resistance, scaling resistance, or strength at elevated or sub-zero temperatures may be required. These are to be as agreed upon by the electrode supplier and the purchaser.

A-3. WELDING CONSIDERATIONS

A-3.1 Before welding or heating any nickel-base alloy, the materials must be clean, oil, grease, paint, lubricants, marking pencils, temperature indicating materials, threading compounds, and other such materials frequently contain sulphur or lead which may cause embrittlement of the base metal or the weld metal if present during welding or heating.

A-3.2 Most of the electrodes in this specification are intended to be used with electrode negative. Some electrodes, however, are designed to operate also on alternating current. Electrodes of this type are so noted in the discussions of each classification (*see* **A-4**).

A-4. DESCRIPTION AND INTENDED USE OF ELECTRODES

A-4.1 ENi Electrode Classification

A-4.1.1 Electrodes of the ENi-1 classification are nickel electrodes used for welding wrought and cast forms of commercially pure nickel to themselves and to steel (that is, joining nickel to steel, surfacing steel with nickel, etc).

A-4.1.2 In dissimilar metal applications, it is important to obtain as little dilution of the weld metal with steel as possible. This can be done by depositing a rather heavy bead of weld metal and dissipating the energy of the arc against the molten weld metal or the nickel-base metal rather

than the steel member. ENi-1 electrodes in the 2·0, 2·5 and 3·15 mm sizes are suitable for welding in all positions. The other sizes are for use in the horizontal and flat positions only.

A-4.2 ENiCu Electrode Classifications

A-4.2.1 Electrodes of the ENiCu classifications are used for welding nickel-copper alloys.

A-4.2.2 Electrodes of the ENiCu-7 classification can be used for welding nickel-copper alloys to themselves, joining nickel-copper alloys to steel, welding the clad side of nickel-copper alloy clad steel and surfacing steel with nickel-copper alloy. For these applications electrodes of this classification are suitable for use in the as-welded or stress-relieved conditions. Electrodes of this classification may be used in all applications recommended for the former types ENiCu-1, ENiCu-2, and ENiCu-4. Electrodes of the 2·0, 2·5 and 3·15 mm sizes may be used for welding in all positions. The other sizes are used in the flat position only.

A-4.3 ENiCrFe Electrode Classifications

A-4.3.1 Electrodes of the ENiCrFe-1 classification are used for welding nickel-chromium-iron alloys.

A-4.3.2 Electrodes of the ENiCrFe-2 classification are used for welding nickel-chromium-iron alloys and for dissimilar metal joints involving carbon steel, stainless steels, nickel-base alloys, and nickel. The metals may be in the wrought form or welding grade castings, or both.

A-4.3.3 Electrodes of the ENiCrFe-3 classification are used for welding nickel-chromium-iron alloys, for welding the clad side of nickel-chromium-iron clad steel, and for surfacing steel with nickel-chromium-iron alloy when comparatively high manganese contents are not detrimental. These electrodes may also be used for welding iron and nickel-base alloy to dissimilar metal combinations. The ENiCrFe-3 electrodes in the 2·0, 2·5 and 3·15 mm sizes can be used for welding in all positions. The other sizes are for use in the horizontal and flat positions. Electrodes of this classification meet more rigid bend test fissure limitations than those for electrodes of the ENiCrFe-1 and ENiCrFe-2 classifications.

A-4.3.4 Electrodes of the ENiCrFe-4 classification are ac-dc electrodes with higher yield and tensile strengths than the ENiCrFe-2 classification and are used for welding 9 percent nickel steel, especially where ac is desired to combat arc blow. These electrodes will also operate with electrode positive.

A-4.4 ENiMo Electrode Classifications

A-4.4.1 Electrodes of the ENiMo-1 classification are used for welding nickel-molybdenum alloys as well as the clad side of nickel-molybdenum alloy clad steel and for welding nickel-molybdenum alloys to other metals. The ENiMo-1 electrodes are normally used only in the flat position.

A-4.4.2 Electrodes of the ENiMo-3 classification are used for welding dissimilar metal combinations of nickel-base, cobalt-base and iron-base alloys. They are normally used only in the flat position.

A-4.5 ENiCrMo Electrode Classifications

A-4.5.1 Electrodes of the ENiCrMo-1 classification are used for welding nickel-chromium-molybdenum alloy to itself, for welding nickel-chromium-molybdenum clad steel and for welding nickel-chromium-molybdenum alloy to other metals. They are normally used only in the flat position.

A-4.5.2 Electrodes of the ENiCrMo-2 classification are used for welding nickel-chromium-molybdenum alloys, for the clad side of nickel-chromium-molybdenum clad steel, and for welding nickel-chromium-molybdenum alloy to other metals. They are normally used only in the flat position.

A-4.5.3 Electrodes of the ENiCrMo-3 classification can be used for welding nickel-chromium-molybdenum alloy, joining nickel-chromium-molybdenum alloy to steel, and surfacing steel with nickel-chromium-molybdenum alloy. These electrodes may be used for welding dissimilar combinations of iron and nickel-base alloys. Electrodes in the 2·0, 2·5 and 3·15 mm sizes can be used for welding in all positions. The other sizes are for use in the flat position only.

A-4.5.4 Electrodes of the ENiCrMo-4 classification are used for welding low carbon nickel-chromium-molybdenum alloy, for welding the clad side of low carbon nickel-chromium-molybdenum clad steel, and for welding low carbon nickel-chromium-molybdenum alloy to other metals. These electrodes normally are used only in the flat position.

A-4.5.5 Electrodes of the ENiCrMo-5 classification are used for welding nickel-chromium-molybdenum alloy, for the clad side of nickel-chromium-clad steel and for joining nickel-chromium-molybdenum alloy to other metals. These electrodes normally are used only in the flat position.

A-4.5.6 Electrodes of the ENiCrMo-6 classification are used for shielded metal arc welding with direct current (either polarity) or alternating current. The latter is used when necessary to combat magnetic arc blow. These electrodes are intended for welding steel used in cryogenic applications, but they can also be used in other applications.

A-5. SPECIAL TESTS

A-5.1 Although welds with electrodes classified by this specification are commonly used in corrosion or heat-resisting applications, it is not practical to specify tests for corrosion or oxidation resistance on welds or weld metal specimens. Such tests which are pertinent to a particular application may be conducted as agreed between the supplier and the purchaser. This section is included for the guidance of those who desire to specify such special tests.

A-5.2 Corrosion or Sealing Tests — Tests of joint specimens have the advantage that the joint design and welding sequence can be made identical to that planned for fabrication. Such specimens have the disadvantage of being a test of the combined properties of the weld metal, the heat-affected zone and the unaffected base metal. It is more difficult to obtain reproducible data if a difference exists in the corrosion or oxidation resistance of the various locations in the joint (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding sequence and joint design are to be considered as variables. Joint specimens for corrosion or oxidation tests should not be used for qualifying the electrode, but they may be used to qualify welding procedures using approved materials.

A-5.2.1 Specimens for testing corrosion or oxidation resistance of the weld metal alone are prepared by following the procedure outlined for the pads for chemical analysis (*see* Appendix C). The pad should be at least 20 mm in height, 65 mm in width and $(25+16n)$ mm in length, where n represents the number of specimens required from the pad. Specimens measuring $13 \times 50 \times 6{\cdot}3$ mm are machined from the top surface of the pad in such a way that the 50 mm dimension of the specimen is parallel to the 65 mm width dimension of the pad and the 12 mm dimension is parallel with the length of the pad.

A-5.2.2 The heat treatment, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms.

A-5.3 Testing for Mechanical Properties — Tests of joint specimens may be desired when the intended application involves the welding of dissimilar metals.

A-5.3.1 Tests of joint specimens may be influenced by the properties of the base metal and welding procedures and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying welding procedures using approved materials rather than for qualifying the electrodes.

A-5.3.2 Where fabrication requires heat treatment of welds, tests of heat-treated specimens will be desirable.

APPENDIX B

(*Clauses* 8.1.1, C-1.1, D-1.1, E-1 *and* F-1)

PARENT METAL FOR TEST SPECIMENS

B-1. Steel — Steel used as the base material for the preparation of test specimens shall be mild steel conforming to IS : 226-1975* (up to and

*Specification for structural steel (standard quality) (*fifth revision*).

including 20 mm thick), or IS : 2062-1969*. The mechanical properties of steel shall be verified from tests on the plate before the test pieces are prepared.

B-2. Nickel and Nickel Alloys — The chemical composition of the nickel and nickel alloys shall suit the chemical composition of the particular electrode under test and shall be subject to agreement between the supplier and the purchaser. The approximate chemical composition of the nickel and nickel alloy used is given below for information:

Base Metal/ Alloy	*Approximate Chemical Composition, Percent*							
	Nickel	Copper	Alumi-nium	Chro-mium	Iron	Molyb-denum	Man-ganese	Sili-con
Nickel (Ni)	90·0	0·25	—	—	0·40	—	0·35	0·35
Nickel-Copper (NiCu-7)	63·0-70·0	Remain-der	—	—	2·5	—	2·0	0·5
Nickel-Chromium-Iron (Ni-Cr-Fe 1, 2, 3 and 4)	72·0 (*Min*)	0·5	—	14·0-17·0	6·0-10·0	—	1·00	0·5
Nickel-Molyb-denum (Ni-Mo)	Remain-der	—	—	—	4·0-6·0	26·0-30·0	1·00	1·00
Nickel-Molyb-denum-Chromium alloy (Ni-Mo-Cr)	Remain-der	—	—	14·5-16·5	4·0-7·0	15·0-17·0	1·00	1·00

NOTE — Single values unless otherwise mentioned indicate maximum values.

APPENDIX C

(*Clauses* 8.2.1, 8.2.2, 8.3.1 *and* A-5.2.1)

TEST FOR CHEMICAL ANALYSIS OF WELD METAL

C-1. PREPARATION OF WELD PAD

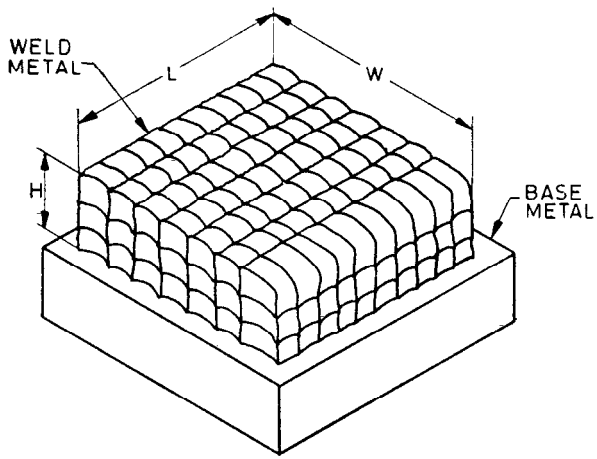
C-1.1 The parent metal used to conduct the chemical analysis shall be according to Table 2 and Appendix B.

*Specification for structural steel (fusion welding quality) (*first revision*).

C-1.2 A weld pad shall be deposited in the flat position on the base plate. Any convenient base plate dimensions may be used. The pad shall be built up of multiple passes and layers. Slag shall be removed after each pass. The temperature of the test plate shall be not less than 15°C prior to welding. The interpass temperature shall not exceed 150°C. The minimum dimensions of the pad of weld metal for the various electrode sizes are shown in Fig. 6. When steel is used as the parent metal the minimum pad height shall be 20 mm and the sample taken for analysis is removed from the pad no closer than 15 mm from the base metal.

C-1.3 The top surface of the pad shall be removed and a sample shall be obtained for analysis by machining, drilling, milling or chipping. The sample shall be free from slag and shall be removed form the pad not closer than 10 mm from the base metal.

C-1.4 When the weld metal is analyzed by accepted analytical methods, the results shall conform to the requirements laid down in Table 1.



Electrode Size	Weld Pad Size, *Min*
mm	mm
2·0	$L = 40$
2·5	$W = 40$
3·15	$H = 13$
4·0	$L = 50$
5·8	$W = 50$
6·3	$H = 13$*

*H to be 20 mm when the base metal is steel.

FIG. 6 DIMENSIONS OF WELD PAD FOR CHEMICAL ANALYSIS TEST

APPENDIX D

(*Clauses* 8.2.1, 8.2.3 *and* 8.2.4)

ALL WELD METAL TENSILE TEST AND TRANSVERSE GUIDED BEND TEST

D-1. PREPARATION OF THE TEST SPECIMEN

D-1.1 The parent metal used in the preparation of test pieces shall be as given in Table 2 and Appendix B.

D-1.2 The test assembly shall be prepared as shown in Fig. 7.

D-1.3 The surfaces to be welded shall be clean, when steel is used as the base metal, the fusion faces shall be overlaid before assembly with two layers of weld metal deposited using the electrode under test. Welding shall be carried out with the plates in flat position using the current and welding technique recommended by the manufacturer.

D-1.4 The temperature of the parent metal shall be not less than 15°C prior to welding. The interpass temperature shall not exceed 150°C.

D-1.5 Welds shall be deposited using a weave not wider than four times the core wire diameter. The completed weld shall be at least flush with the surface of the test plate. The root layer may be deposited using 2·5 or 3·15 mm size electrodes.

D-1.6 Prior to welding the assembly may be preset so that the welded joint will be sufficiently flat to facilitate removal of test specimen. As an alternative restraint or a combination of restraint and preset may be used to prevent warpage in excess of 5°. A welded test assembly that has warped more than 5° shall be discarded. Welded test assemblies shall not be straightened.

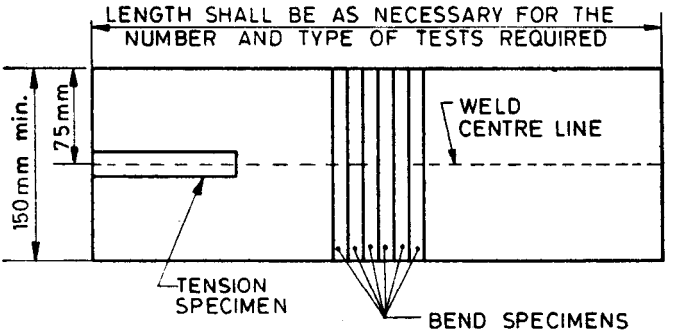
D-2. ALL-WELD METAL TENSILE TEST

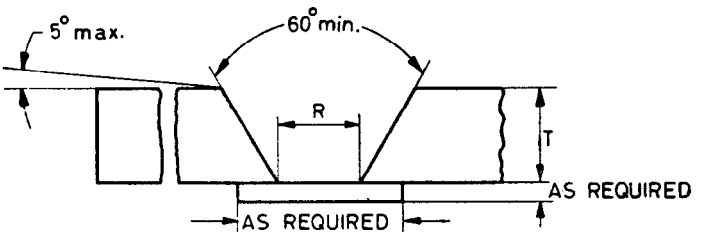
D-2.1 One all-weld metal tensile test specimen shall be machined from the test assembly prepared as shown in Fig. 7. Welding shall be done in the flat position as stated in **D-1.3**. The test shall be conducted in the as-welded condition. The test shall be conducted by using well accepted methods but shall generally be in accordance with IS : 1608-1972*. The dimensions and orientation of the test specimen shall be as shown in Fig. 8.

D-3. TRANSVERSE GUIDED BEND TEST

D-3.1 When transverse guided side bend tests are required by Table 2, six such specimens shall be taken from the test assembly as shown in Fig. 7.

*Method for tensile testing of steel products (*first revision*).





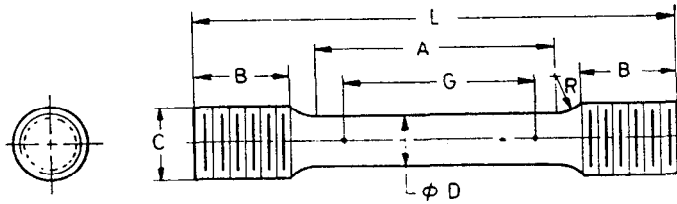
Groove Preparation of Test Plate

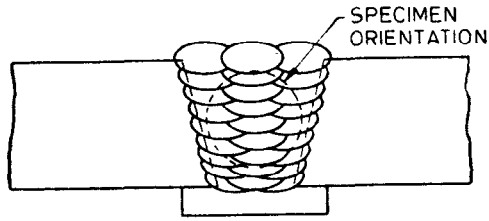
Electrode Size mm	*T* Minimum Test Plate Thickness mm	*R** Maximum Root Opening mm	Number of Layers, Minimum
2·0	8·0	5·0	†
2·5	12·0	6·0	†
3·15	12·0	6·0	†
4·0	20·0	12·0	6
5·0	20·0	12·0	6
6·3	20·0	12·0	6

*Tolerance on *R* is $\pm$1·5 mm.

†Number of passes not specified, but pass and layer sequence shall be recorded and reported.

FIG. 7 WELDED JOINT FOR ALL-WELD METAL TENSILE TEST AND TRANSVERSE GUIDED BEND TEST



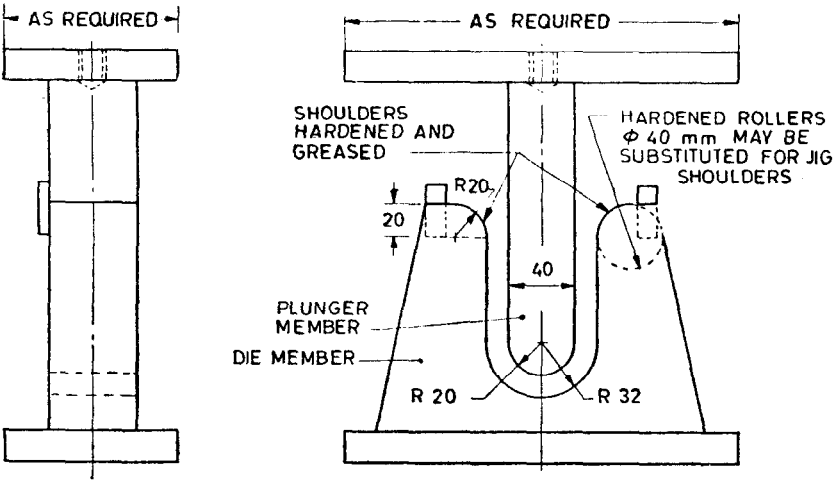


	Dimensions, mm		
	12·8 Specimen	6·4 Specimen	4·8 Specimen
Test plate thickness	20	12	**8**
G — Gauge length	50 ± 0·15	25 ± 0·15	19 ± 0·08
D — Diameter	12·5 ± 0·30	6·4 ± 0·15	4·8 ± 0·08
R — Radius of fillet	10 *Min*	5 *Min*	3 *Min*
A — Length of reduced section	55 *Min*	31 *Min*	26 *Min*
L — Overall length	125 approx	75 approx	50 approx
B — Length of end section	35 approx	22 approx	12 approx
C — Diameter of end section	**20**	**10**	**6**
Approximate area, mm²	123	32	13

NOTE — End sections may or may not be threaded. Threads, when employed, should be machined to fit available fixture.

FIG. 8 DIMENSIONS FOR ALL-WELD METAL TENSION TEST SPECIMEN

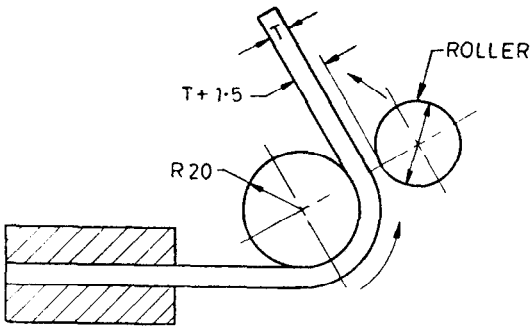
The size of specimen shall be $10 \times T \times 150$ mm where T is the thickness of the test plate. When face bend test specimens are required (for 2·0 mm size electrodes as stated in Table 2), two such specimens shall be taken from the assembly shown in Fig. 7, the size of specimen being $8 \times 40 \times 150$ mm. In both cases the test specimen shall be uniformly bent (in the as-welded condition) through 180° over a 20 mm radius in any suitable jig. Positioning of the side bend specimens shall be such that the side with greater discontinuities, if any, is in tension. Positioning of the face-bend specimens shall be such that the face of the weld is in tension. For both types of specimens, the weld shall be at the centre of the weld. Two types of jigs are shown in Fig. 9 and 10. After bending the welded joint shall conform to 20 mm radius plus an appropriate allowance for springback.



All dimensions in millimetres.

NOTE — The side of the specimen turned toward the die shall be the face for the face-bend specimens and the side with the greater defects, if any, for the side-bend specimens.

FIG. 9 GUIDED-BEND TEST JIG



All dimensions in millimetres.

NOTE 1—Dimensions not shown are the option of the designer. It is essential to have adequate rigidity so that the jig parts will not spring.

NOTE 2—The specimen shall be firmly clamped on one end so that it does not slide during the bending operation. The weld and heat-affected zone in the case of the transverse weld bend specimens shall be completely within the bent portion of the specimen after testing.

NOTE 3—Test specimens shall be removed from the jig when the outer roll has been rotated through 180° from the starting point.

NOTE 4—When using the wraparound jig, the side of the specimen turned toward the roller shall be the face for the face-bend specimens, and the side with the greater discontinuities, if any, for the side-bend specimens.

FIG. 10 ALTERNATE WRAPAROUND GUIDED BEND TEST JIG

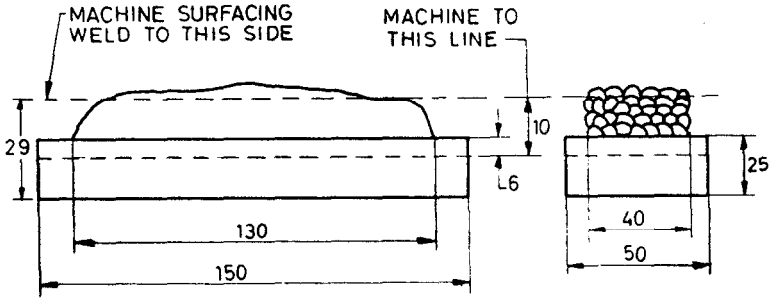
APPENDIX E

(*Clauses* 8.2.1, 8.2.5 *and* 8.3.1)

SURFACING WELD BEND TEST

E-1. The parent metal for plates used in the preparation of test pieces shall be mild steel as given in Table 2 and Appendix B.

E-2. One surfacing weld test specimen shall be made according to the dimensions given in Fig. 11.



All dimensions in millimetres.

FIG. 11 SURFACING WELD BEND TEST SPECIMEN

E-3. The electrical conditions and operating techniques employed in this test shall be those recommended by the supplier. The welding shall be done in flat position.

E-4. An interpass temperature of 120°C shall be maintained. The weld shall be cleaned thoroughly after the deposition of each pass and prior to the deposition of the next.

E-5. Upon completion of the surfacing weld, the weld should be mechnined or ground evenly and a surfacing weld bend test specimen shall be prepared according to Fig. 11.

E-6. The test specimen shall then be uniformly bent through 180 degree (in the as-welded condition) over a 40 mm diameter, in any suitable jig (*see* Fig. 9 and 10 for typical jigs), positioning the specimen such that the surfacing weld will be in tension.

E-7. The surfacing weld metal after bending shall not exhibit evidence of fissuring in excess of the requirements of Table 4 when examined by the naked eye.

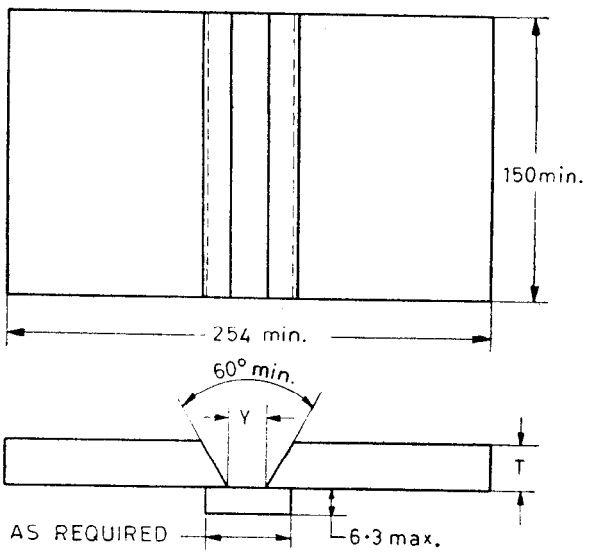
APPENDIX F

(*Clauses* 0.3, 8.2.1 *and* 8.2.6)

USABILITY TEST

F-1. The parent metal used in the preparation of the usability test specimen shall be as given in Table 2 and Appendix B.

F-2. The test assembly shall be as shown in Fig. 12.



All dimensions in millimetres.

Electrode size, mm	2·0	2·5	3·15	4·0	5·0	6·3
T = Thickness minimum, mm	3·15	6·3	10·0	12·0	12·0	12·0
Y = Root opening*, mm	3·15	6·3	8·0	10·0	12·0	12·0

*Tolerance : ±1·6 mm.

FIG. 12 TEST PIECE FOR USABILITY TEST

F-3. The surfaces to be welded shall be clean. Each weld bead shall contain a start in the area to be evaluated. Welds shall be deposited using a weave not wider than four times the core wire diameter. The root layer for test of electrodes longer than 3·15 mm may be deposited using 2·5 or 3·15 mm electrodes. Welding shall be conducted in the vertical or flat position as indicated in Table 2.

F-4. The completed metal shall be at least flush with surface of test plate.

F-5. The temperature of the parent metal shall be not less than 15°C prior to welding. The interpass temperature shall not exceed 150°C.

F-6. After completion of the weld, the weld reinforcement and backing strip shall be removed flush with the surfaces of base plate and the assembly shall be radiographed generally in accordance with IS : 2595-1963*, with a radiographic resistivity of 4 percent.

*Code of practice for radiographic testing.

(*Continued from page* 2)

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Printed at New India Printing Press, Khurja, India